A CASE STUDY OF PERIARTICULAR FRACTURES OF THE TIBIA MANAGED WITH HYBRID EXTERNAL FIXATOR APPLICATION

DISSERTATION SUBMITTED FOR

M.S. DEGREE

(BRANCH II - ORTHOPAEDIC SURGERY)

MARCH 2009

THE TAMILNADU
DR. M.G.R. MEDICAL UNIVERSITY
CHENNAI, TAMILNADU

DEPARTMENT OF ORTHOPAEDICS
MADURAI MEDICAL COLLEGE AND
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MADURAI.

CERTIFICATE

This is to certify that the dissertation entitled "A CASE STUDY OF PERIARTICULAR FRACTURES OF THE TIBIA MANAGED WITH HYBRID EXTERNAL FIXATOR APPLICATION" is a bonafide record of work done by ***Dr. P. SAI PRASAD*** in the Department of Orthopaedics and Traumatology, Government Rajaji Hospital, Madurai Medical College, Madurai, under the direct guidance of me.

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DECLARATION

I **Dr. P. SAI PRASAD,** solemnly declare that the dissertation entitled "**A CASE STUDY OF** PERIARTICULAR FRACTURES OF THE TIBIA MANAGED WITH HYBRID EXTERNAL FIXATOR APPLICATION' has been prepared by me under the able guidance and supervision of my guide **Prof.Dr. V. Raviraman, M.S.ORTHO., D.ORTHO., Prof & HOD,** Department of Orthopaedics and Traumatology, Madurai Medical College, Madurai, in partial fulfillment of the regulation for the award of **M.S. (ORTHOPAEDIC SURGERY)** degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in March 2009.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

Place : Madurai

Date : **DR. P. SAI PRASAD**

ACKNOWLEDGEMENT

I am deeply indebted to my beloved chief and my teacher, Prof. Dr**. V. Raviraman, M.S.Ortho, D.Ortho., Professor and Head of the Department of Orthopaedics, Madurai Medical College,** Madurai for the able guidance, inspiration and encouragement he has rendered at every stage of this study.

I am grateful to my beloved teachers **Prof. Dr. Malairaju, Prof. P.V. Pughalenthi, Prof. Dr. A. Rajamani, Dr. T. Chandraprakasm** for their invaluable help and guidance rendered to me in preparing this dissertation.

I express my heartfelt gratitude to my beloved teacher **Dr.S.Shanmuganathan.,** for his able guidance, inspiration and encouragement he has rendered at every stage of this study.

I express my heartfelt gratitude to **Dr.V.Ramar, Dr.R.Sivakumar, Dr.K.Ravichandran, Dr.V.R.Ganeshan, Dr.R. Arivasan, Dr. M.N. Karthi, Dr.N.Thanappan,** Assistant Professors of Orthopaedics, Madurai Medical College, Madurai for their valuable advice and help in carrying out this study.

I sincerely acknowledge with gratitude the guidance and persistent encouragement given to me by **Dr. B. Sivakumar, Dr. S.Ramanathan, Dr. P.V.Thirumalai Murugan, Dr. K.P. Saravana**

Kumar, Dr. J. Manikandan, Dr.T.C. Premkumar, Dr. Durai Murugan and all our assistant professors.

My sincere thanks to **Prof. Dr. S.M. Sivakumar, M.S., Dean, Madurai Medical College,** Madurai for permitting me to utilize the clinical materials of the hospital.

I would like to thank my patients, friends and colleagues & family who have stood by me throughout this work and above all the **GOD FOR HIS KINDNESS THROUGHOUT THIS STUDY**.

CONTENTS

INTRODUCTION

Increased incidence of Road Traffic Accidents, natural disasters, industrial accidents claim most of human mortality and morbidity. Hence, it forms the major epidemic of Modern Era. Of these, fractures of Proximal and distal tibia have historically been difficult to treat. In this modern era of increasing life expectancy, there is a rise of old age population which, increases the incidence of these fractures in osteoporotic bones, adding to the morbidity.

Because of the proximity of these fractures to the knee and ankle joint, regaining full knee and ankle motion and function may be difficult. Soft tissue damage, comminution, fracture extension into the knee or ankle joint lead to unsatisfactory results in many cases regardless of the treatment modality.

Better understanding of the injury patterns, availability of better implants, the concept of early surgical fixation and early postoperative mobilization of joint all have convincingly improved the functional outcome of the patient to a large extent.

Main challenges encountered in the treatment of periarticular fractures of tibia are

- these high energy fractures are associated with extremely damaged soft tissue envelop leading to increased incidence of compound injuries which results in increased complications following open reduction and internal fixation. Also communition of metaphysis and articular surface makes anatomical reduction difficult. The resulting incongruency of articular surface leads to early secondary OA.
- In metaphysis fixation is less satisfactory resulting in early loosening of implant.
- communited fractures create difficulty in achieving rigid fixation due to poor purchase and are less optimal to permit weight bearing or even early joint mobilization.

Initially conservative treatment with POP was advocated as a treatment option. But it lead to high incidence of malunion and stiffness of adjacent joints. Also prolonged recumbency resulted in high incidence of thromboembolic diseases and pneumonia. Open reduction and internal fixation with plate osteosynthesis lead to skin necrosis and infection in > 40% of patients eventually leading to malunion and implant failure. Intramedullary devices gives inadequate stability due to wide medullary cavity leading to implant failure and screw breakage. For compound injury patients, initial treatment with external fixator for wound care and then followed by definitive mode of fixation was advocated. This involves multiple procedures which increased economical and mental stress for the patients. But hybrid fixation is a single definitive procedure, helping both in wound care and aiding in sound union of fracture.

They also offer advantages of applying multiple pins according to varying fracture pattern without disturbing the soft tissue cover; less chances of infection, early mobilization of patient, reducing the tendency for varus collapse and at the same time afford better stability.

The successful management of these injuries, demands thorough knowledge of fracture personality, technical aspects of fracture fixation and the tailored post operative management.

AIM

- To discuss the management of periarticular fractures of tibia
- To evaluate the biomechanical and biological advantages of hybrid fixators
- To evaluate clinical, functional and radiological outcome after hybrid fixator application

REVIEW OF LITRATURE

Intra-articular and juxtra articular fractures are the most commonly occurring injuries. There has been a long debate on merits and demerits of operative and non operative mode of management. Numerous investigators have reported satisfactory reports with either closed or open methods of treatment. The out come of fracture depends upon the integrity of soft tissues.

Tracy Watson et al studied the biomechanics of hybrid fixator frame and suggested that biomechanical data support the use of tensioned wire and hybrid fixator for stabilizing complex fractures of proximal tibia.

In 1994 he studied 31 patients of tibial plateau fractures for whom hybrid fixators were applied. Bone healed in an average of 15 weeks and the knee range of movement was 106 degrees. He reported excellent report in 27 of 31 patients.

Stamer et al[36] reported 70% good to excellent results in tibial plateau fracture patients treated with hybrid external fixator.

Micheal S sirkin et al[25] from their study concluded that hybrid external fixator is most appropriate for patients with tibial plateau fractures.

Rueidi Allgower[34] showed 70% good to excellent results with open reduction and internal fixation of intra articular fractures of lower end of tibia. They recommended the following principles of treatment

- restoration of length
- reconstruction of articular cartilage
- ability to treat metaphyseal defect with bone graft when needed
- provision of buttress to restore axial alignment

Kevin et al[19] showed that a combination of minimal internal fixation with external fixation fulfils all these principles. He reported a union rate of 85% with minimal internal fixation and unilateral external fixator and a union rate of 93% with hybrid fixator and time of union is 7.1 months.

Tornetta et al [39] used ring fixator to treat tibial pilon fractures and he reported 100% union rate with an average time of union of 4.2 months.

Mark Farrer et al reported 75% good to excellent results in high energy tibial plafond fractures which is treated with Sheffield hybrid fixator which relies on one full ring for metaphysis and diaphysis. They compared Sheffield hybrid fixator with primary open reduction and internal fixation with good to excellent result in 81% compared to 77% in the later. They emphasized the importance of anatomic reduction of articular surface which significantly improves the out come.

Rocco Barbieri et al[33] reported 37 distal tibia fractures fixed with hybrid fixators and reported 12 excellent, 9 good, 7 fair and 6 poor results. The results were acceptable in 82% and poor in 18%.

Leener et al[20] studied the use of hybrid external fixators in stabilizing peri articular, supracondylar and pilon fractures.

Enders et al 14 studied a total of 62 tibial pilon fractures and reported good results in 87% of people treated with hybrid and only 38% of people treated with other conventional methods.

Robert et al[32] studied strategies to improve frame stability of hybrid external fixator and concluded that dramatic improvement of stability can be achieved from addition of an anterior proximal half pin.

BIOMECHANICS

Hybrid external fixator presents mechanical characteristics that set apart significantly from other systems of external fixator. It characteristics can be called as solid-elastic. Solid enough for stabilization and still providing micro motion which enhances good callus formation.

Three theoretical and biomechanical foundation of hybrid external fixator are

- minimal damage to vascularity and soft tissue
- solid yet elastic stabilization
- Immediate resumption of function.

Two separate components exits for hybrid external fixator

1. Ring fixator
2. AO external fixator

RING FIXATOR

Important factors governing rigidity is bone contact, which gives axial stiffness. The number of wires gives torsional stiffness. 1.5 Or 1.8 mm K wires are used. The amount of tension depends on frame stiffness and weight of the patient. Generally a tension of 100 – 130 kg is given. Tensioning reduces the deflection of the wire due to bending and increases the bending stiffness. Bending stiffness is directly proportional to fourth power of its diameter. A cluster of 4 or more k wires provides increased stiffness. Increasing the number of wires distributes the load from the injured region to intact trabecular bone surrounding the injury.

AO EXTERNAL FIXATOR

Factors affecting rigidity are

- number of pins
- diameter of pins distance of side bar from bone
- separation of pins around fracture site
- geometry of fixator

HALF PIN

It forms the back bone of the fixator. It ranges from 3-6 diameters and it is self tapping. It is effective in stabilizing diaphysis and has less chance of neurovascular injury. Stiffness of pin depends on core diameter, long or short thread and diameter of shaft of pin.

When a long bone fracture is loaded in bending, the pins are loaded as cantilever beam, with load at bone / pin interface. Highest stress is at cortical surface where exits pin. Bone stress decreases by decreasing side bar bone distance and increasing pin diameter.

DESIGN RATIONALE

The main aim is to hold the fragment in proper alignment while allowing minimal axial dynamization at fracture site. Laryon and Rubin showed that cyclic axial loading of bone is important for maintaining bone mass and remodeling. Woodship, kenwight and Wolf et al demonstrated that axial micromotion at fracture site increased fracture healing. Fixation of metaphysis with K wire is safer since pin pull out is greatly reduced. Fixation of diaphysis using half pin is safer by decreasing neurovascular damage. Also early range of motion can be started .

STIFFNESS

The slope of load deflection curve of fixation system is known as fixator stiffness. In case of spiral fracture with cortical contact , direct lag screw fixation produces 50- 70% of bending stiffness while DCP and external fixator provides 82- 160% of stiffness. In axial compression , plate and external fixator provides 90- 115% of stiffness and ilizarow provides 69- 117% of stiffness. Lag screw provides 9% of torsional stiffness and plate and external fixator 40- 64% and intramedullary rod 6.5% of stiffness.

This shows external fixator is very effective for bending and axial loading and ring fixator is very effective in metaphysis for torsional stiffness. uniplanar fixator is stiffer than ilizarov in lateral stress whereas ilizarow is stiffer in AP bending and torsion. So combination of these both gives stiffness comparative to both of these fixators.

SHEAR STIFFNESS

Ability of fixator to resist translation shear at fracture site is shear stiffness. Hybrid fixator resists shear forces as other fixators

AXIAL STIFFNESS

Ability of fixator to resist gap closure is known as axial stiffness. Bone contact is most important in giving axial stiffness. Hybrid fixator with good bone contact has axial stiffness less than external fixator and equivalent to ilizarow fixator. This allows axial micromotion.

TORSIONAL STIFFNESS

Ring fixator with K wire increases torsional stiffness than external fixator. Torsional stiffness increases upto 280 with pin angle of 90 deg.

MATERIAL AND PROPERTIES

The material used should with stand corrosion and should be sufficient to with stand stresses. It depends on the composition of material involved, grain size and porosity. The composition of stainless steel is iron, 17- 20% chromium, 10-17% of nickel, 3% manganese, phosphorus, sulfur, silicon, 2-4% molyblendum and < .03% carbon. The composition of titanium alloy is titanium, 5.5- 6.5% alum, 3.5- 4.5% vanadium, 0.46%iron, carbon and oxygen. Titanium modulus of elasticity closes to humerus bone and is very much corrosive resistant due to oxide film. It has an excellent fatigue resistance. Other alloys are carbon fibre (side rods), cobolt chromium alloy (bone screws).

ANATOMY OF PROXIMAL AND DISTAL TIBIA

Bony articular surface of proximal tibia slopes inferiorly 10 degree from anterior to posterior. Between the medial and lateral plateau there lies the intercondylar eminence which has medial and lateral tibial spines which are areas of attachments for menisci and cruciate. Tibial tubercle which is present on the anterior surface of tibial crest 2.5 to 3 cm below joint line gives attachment for patellar tendon. Gerdy's tubercle which lies in the antero lateral surface of lateral tibial flare receives insertion of ilio tibial band.

Proximal tibiofibular joint is located posterolaterally on tibial condyl. The head of fibula gives attachment to fibular collateral ligament and biceps tendon.

Tibial plateau is covered by hyaline cartilage 3mm thick on medial plateau and 4mm thick on lateral side. Medial plateau is larger and is concave from front to back as well as from side to side. Lateral plateau is smaller in size and higher than medial. It is convex from front to back and from side to side. Outer portion of each plateau is covered by fibrocartilage.

Medial articular surface and subcondylar medial plateau is stronger than lateral side. So in low violence injuries lateral condyl fractures are more common.

The bony anatomy of ankle joint gives stability in dorsiflexion and relative mobility in plantar flexion. In dorsiflexion stability is provided by articular contact and in plantar flexion by the ligamentous structures.

The talar dome is wider anteriorly than posteriorly. As the ankle dorsiflexes, the fibula rotates externally to accommodate the widened anterior surface of talus.

CLASSIFICATION OF PROXIMAL TIBIA FRACTURES

Various classification system were proposed since past to aid in treatment of proximal tibial fractures. In 1956 Hohl and Luck were the first to classify proximal tibial fractures into non displaced, local depression, split depression and split fractures. Later Hohl expanded the classification as local compression, split compression, total, split and communited.

Then Moores classification came to role.

Type I split fractures (which also includes coronally split unstable fractures)

Type II fracture involving entire condyl

Type III Rim avulsion fracture

Type IV Rim compression fractures

Type V communited bicondylar fracture with intercondylar eminence as Separate fragment resulting in four part fracture

Again Hohl revised his classification including Moores classification. He classified fractures into minimally displaced which are less than 4 mm displaced and displaced. Displaced fractures are further classified into 6 types

1. Local compression
2. Split compression

3. Total depression
4. split fracture
5. Rim fracture
6. Bicondylar fracture

AO classification for proximal tibia fractures

A1 - Tibial spine avulsion fracture

A2 - extraarticular fracture

A3 - extraarticular communited fracture

B1 - Lateral condyl split fracture

B2 - lateral condyl compression fracture

B3 - lateral condyl communited fracture

C1 - Bicondylar fracture

C2 - Bicondylar fracture with metaphyseal communition

C3 - Bicondylar fracture with intra articular communition

Most commonly followed classifications for proximal tibia fractures are that proposed by Schatzker.

Low energy fractures:

Type I

Split facture of Lateral plateau without articular depression. It occurs in young adults with strong cancellous bone. If it is displaced lateral meniscus is often torn.

Type II

Split depression fracture of lateral tibial condyl. It occurs more commonly during 4th decade. It occurs due to lateral bending force with axial loading.

Type III

Isolated depression fracture of lateral plateau. This type is usually associated with joint instability

High energy fracture patterns

Type IV

Fracture of medial plateau. It is caused by varus force with axial loading. This type is less common and is associated with cruciate, lateral collateral, peroneal nerve and popliteal artery injuries.

Type V

Bicondylar plateau fracture

Type VI

Bicondylar tibial plateau fracture with diaphyseal metaphyseal dissociation. This type is commonly associated with compartmental syndrome, neurovascular compromise and compromise to soft tissue.

CLASSIFICATION OF DISTAL TIBIA FRACTURES

Reudi and Allgower's was the first classification came to use.

Type I - non displaced cleavage fractures of joint

Type II – displaced fractures with minimal communition

Type III – displaced fractures with severe communition.

This classification has a prognostic significance prognosis being poor as the type increases from type I to type III.

AO/ OTA classification is now universally used for distal tibial fractures.

Type A – non articular fractures

Type B – partially articular fractures

Type C – total articular fractures (tibial plafound fractures).

MECHANISM OF INJURY

Tibial plateau fractures results due to strong valgus or varus force combined with axial loading. Location of fracture depends on degree of flexion or extension of knee. When a patient sustains valgus or varus force with axial loading, respective femoral condyl exerts both shearing and compressive force on underlying tibial plateau. This result in split fracture , depressed fracture or both. Isolated split fractures occurs in young adults with dense cancellous bone capable of withstanding compressive force. With age cancellous bone becomes sparse and not able to with stand compressive force causing depression or split depression even in low energy force.

Intact collateral ligaments on one side is necessary for fracture on contralateral plateau. For e.g. Medial collateral ligament acts as hinge for valgus force to drive lateral femoral condyl to tibial plateau causing fracture.

Lateral condyl fracture is associated with tears of medial collateral ligament and cruciate ligament. Medial condyl fracture is associated with lateral collateral ligament, cruciate ligament , lesion of peroneal nerve and popliteal vessels.

Tibial plafond fractures occur due to motor vehicle accidents or due to fall from height. Bone is viscoelastic, so in axial loading bone absorbs more energy and release more energy, which is imparted to soft tissues. This results in tense swelling, fracture blisters and complicates the treatment. Axial loading injuries causes articular surface and metaphyseal communition and severe soft tissue injuries. To include in Tibial plafond fractures fracture line should transverse weight bearing articular surface of distal tibia.

INVESTIGATIONS

Clinically the patients may present with symptoms and signs either of fractures (or) other major problems like hypovolemic shock.

All patients with fracture upper end of tibia should be looked for peripheral pluses.

A good quality X ray in two perpendicular views is a must to look for the joint involvement.

- Computer tomography portrays the proximal and distal tibia in cross- section, which helps to identify fracture lines in the frontal plane. Two and three dimensional reconstructions may also improve understanding of the fracture pattern in preparation for surgery. But in our study, we haven’t taken CT for any patients due to economical constraints.

PRINCIPLES OF MANAGEMENT

There are a lot of factors which play a dynamic role in management. They include.

1. Amount of fracture displacement
2. Degree of comminution
3. Extent of soft tissue injury
4. Associated Neurovascular injuries
5. Magnitude of joint involvement
6. Degree of Osteoporosis
7. Associated injuries
8. Complex ipsilateral fractures (eg patella/plateau fracture)

The main goal of fracture treatment is obtaining a stable, aligned, mobile and painless joint to minimize post traumatic osteo arthritis

So the objective of treatment of Periarticular fractures of Tibia is

1. To obtain and maintain satisfactory reduction and stable fixation.
2. To regain a functional range of motion of knee and ankle joint
3. To avoid varus collapse of knee joint.
4. To treat the associated injuries.

The prognosis of fracture depends on

- degree of articular depression
- extend of condylar separation or widening
- degree of diaphyseal metaphyseal communition and dissociation
- integrity of soft tissue envelope

METHODS OF TREATMENT

The principles of treatment are

- An articular fracture with joint instability needs open reduction and internal fixation
- Joint congruency should be restored
- Anatomical reduction and stable fixation of articular fragment are necessary for articular cartilage regeneration
- If open reduction and internal fixation is inadvisable due to Patient conditions skeletal traction and early motion should be advocated

In the decade of 1960s, conservative treatment methods such as traction and cast bracing, produced better results than operative treatment, because of the lack of adequate internal fixation devices. It had a high incidence of malunion and Stiffness of adjacent joints. Also prolonged recumbency caused thromboembolic disease and pneumonia.

With the development of improved internal fixation devices, treatment recommendations begin to change in 1980s. Open reduction and internal fixation with buttress plates was done. Due to the poor soft tissue cover it caused skin necrosis in both proximal and distal tibia which leads to high chances of infection. Also low profile plate leads to chances of implant failure and eventually malunion.

Intramedullary rods were used which had Inadequate stability due to wide medullary cavity both in proximal and distal tibia which lead to Implant failure and screw breakage. Also entry point was difficult in case of proximal tibia due to extension of fracture line.

External fixation was used as either temporary (or) definitive fixation in severe open proximal and distal tibia fractures especially those associated with vascular injury. Since it is a form of Rigid fixation, union was delayed. Also it Spans the joint and hence chances of joint stiffness are more.

A recent advance in technology for the treatment of proximal and distal tibial fractures includes minimally invasive reduction of fracture and application of hybrid external fixator. They offer advantages of applying multiple pins according to varying fracture pattern without disturbing the soft tissue cover, less chances of infection, early mobilization of patient, reducing the tendency for varus collapse and at the same time afford better stability.

So management of distal femur fracture can be divided into two broad categories.

1. **conservative treatment**
2. **operative treatment**

In operative treatment, various modalities include

1. Open Reduction Internal Fixation with buttress plate
2. Open Reduction Internal Fixation with locking compression plate
3. Open Reduction Internal Fixation with Cancellous screws
4. Closed reduction & internal fixation with expert tibial locking nails.
5. Ilizarov ring fixation
6. External fixation.
7. Hybrid external fixator application

CONSERVATIVE MANAGEMENT

Considerable controversy existed as to whether conservative (or) surgical treatment leads to better results for management of periarticular fractures of tibia. Early attempts at internal fixation of these complex injuries were associated with high incidence of malunion, nonunion and infection. Because of the increased risk of complications, numerous authors concluded that closed methods were preferable to operative treatment.

With the improvement in surgical techniques, availability of better implants, prevalence of better antibiotics, the operative management has got many recommendations in treatment of periarticular fractures of tibia. The indications for conservative therapy include.

1. Undisplaced (or) Incomplete fractures with intact collateral ligaments.
2. Fractures displaced less than 5mm
3. Elderly sedentary patients with depression less than 8 mm
4. Impacted stable fracture in elderly osteoporotic patients.
5. Lack of modern internal fixation devices.
6. Unfamiliarity or inexperience with surgical techniques.
7. Significant underlying medical disease

The goals of conservative treatment are not anatomical reduction of fracture fragment but restoration of overall length and axial alignment. The criteria's for acceptable fracture management include

1. $< 7^0$ malalignment in frontal plane.
2. $< 10^0$ malalignment in sagittal plane
3. Limb shortening < 1.5 cm.
4. Articular incongruity < 2 mm

Various methods of conservative management include

1. Supramalleolar pin traction in a BB splint
2. Hinged knee brace locked in full extension. For the first two weeks progressive range of movements are started aiming to achieve 90 degrees with in 4 weeks. Brace is worn for 8 -12 weeks

SURGICAL MANAGEMENT

INTRODUCTION:

In the past 25 years, various forms of treatment for fixation of fractures of upper and lower end of tibia have evolved. The combination of a better understanding of fracture pattern, importance of soft tissue handling, judicious use of antibiotics, and improved imaging techniques have brought the evaluation of different modes of minimally invasive fixation practical. Since 1980, various studies have comparing the results of various modes of fixation for periarticular fractures of tibia giving variable results.

The goals of operative treatment of periarticular fractures of tibia are

a) Anatomical Alignment

b) Stable fixation

c) Early Mobilization

d) Early functional rehabilitation of knee and ankle.

Indications for operative management include

1) Displaced intraarticular fracture

2) Patients with Multiple injuries

3) Open fractures

4) Associated vascular injuries requiring repair.

5) Severe ipsilateral limb injuries (patellar fracture, tibial plateau fractures)

6) Major associated knee ligamentous injuries.

7) Irreducible fracture.

8) Pathological fracture

Contraindications to internal fixation include

1) Active infection

2) Inadequate facilities

3) Inexperienced surgeons

Timing of surgery

- for open injury, compartmental syndrome and vascular injury immediate treatment is needed
- for displaced unstable fractures surgery is done as early as condition of patient permits
- After stabilization of neurosurgical, abdominal and thoracic injuries
- For critically ill patients, percutaneous fixation with temporary joint spanning external fixator
- Open reduction and internal fixation is done after soft tissue swelling subsides and local skin conditions permits

PROCEDURE

Sequences in the surgical management of tibial plateau and pilon fracture includes

1) Restoration of articular surface
2) Metaphyseal alignment.
3) Defect filled with bone graft
4) Early mobilization of joint.

1. CANCELLOUS SCREW FIXATION:

Cancellous screw fixation alone can be done in case of low violence fractures of tibial plateau (type I, II, III). Usually 6.5 mm screws should be used. Cancellous screws can be applied percutaneously after indirect reduction of fragments under fluoroscopic control or after open reduction of fragments. If joint depression is present it is elevated, filled with bone graft and then fixed with cancellous screws. It is also used in conjugation with other modes of fixation e.g. Hybrid external fixator.

2. LATERAL BUTRESS PLATE:

Previously lateral buttress plates are used extensively for internal fixation of tibial plateau fractures. Once it was placed after extensile approach and open reduction which has lead to the problems of wound dehiscence, infection and plate exposure. Nowadays lateral buttress plate is used after minimal open reduction in which reduction is achieved using femoral distractor and articular surface is elevated through a small cortical window made in the anterior tibia. Lateral buttress plate is slided extra periostealy and fixed. Support to medial column was provided using a small plate in the postero medial tibial surface or with half pin external fixator on medial side which is kept for 6 – 10 weeks.

3. HYBRID EXTERNAL FIXATOR:

It is a Combination of wire (ilizarov) and pin fixation.

It doesn’t span the joints, so early mobilization can be done thus reducing the chances of joint stiffness. Also early mobilization helps in the good healing of articular cartilage. It is a more stable and also less rigid fixation allowing axial micro motion thus favoring good bony union.

4. INTRAMEDULLARY NAILS:

Intramedullary nailing has received increased attention for the treatment of distal femoral fractures. These devices obtain more biological fixation than plates because they are load sharing rather than load bearing implants. They offer greater soft tissue preservation. But interlocking nail cannot be used in periarticular fractures of tibia due to the difficulty in entry point and difficult in locking. To over come this newer methods of nails such as expert tibial nail has been introduced to deal with periarticular fractures of tibia.

5. Locking compression plate

The screw holes in plate have been specially designed to accept either a standard cortical screw with a hemi spherical head or a locking screw with a threaded head. It is used as less invasive skeletal stabilization by sliding the plate without disturbing the soft tissues. A locked screw plate construct can be compared to an implanted external fixation device.

COMPONENTS AND INSTRUMENTS OF HYBRID FIXATOR

Hybrid fixator consists of 3 components.

RING SYSTEM

It consists of k wires, olive wires, wire fixation bolts, 5/8th ring, bolts, nuts and posts.

PIN SYSTEM

It consists of schanz screw, AO tube and universal clamp.

INTERCONNECTING SYSTEM

Male post connected with AO clamp

K WIRE

K wire was named after Martin Kirschner. Depending on the type of tip it is differentiated into two types – trocar point has 3 cutting edges. It is used in fixation of cancellous bones; diamond tip has beveled edge, which is used in cortical bones. Stiffness of k wire is directly proportional to 4th power of radius. For tibia and femur 1.8 mm k wire of 300mm length is used.

HALF PINS

It does not pass beyond the far cortex. They are round at one end and threaded at other end. They are self tapping and available in 3-6mm of diameter. 4.5×175 mm is used for tibia and 4.5×200mm for femur

SIDE TUBE

It is the long stress bearing segment. It is 11mm in diameter and available in lengths of 100-450in 50mm increments and 550&650. SS rod is tubular with 11mm outer diameter and 9mm inner diameter. Carbon fiber rod is solid with11mm diameter and is radiolucent.

UNIVERSAL CLAMP

It is used for connecting 4.5 or 5mm schanz screw with side tube. This allows pin insertions for angle adjustments over 15 deg in frontal plane.

RING

In hybrid 5/8th is used, availability ranging from 120-220.

INTERCONNECTION

Swivel from universal clamp is removed and connected to male post, which is attached to 5/8th ring.

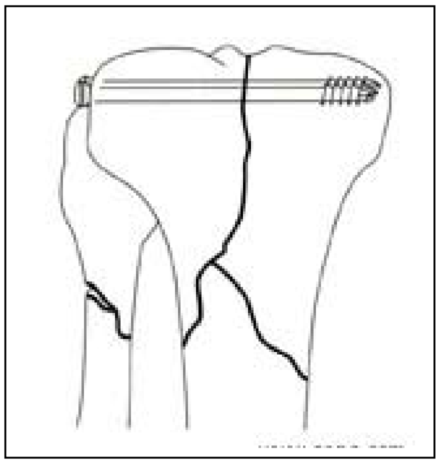
STABILITY OF FIXATOR:

Stability of fixator can be increased by the following techniques

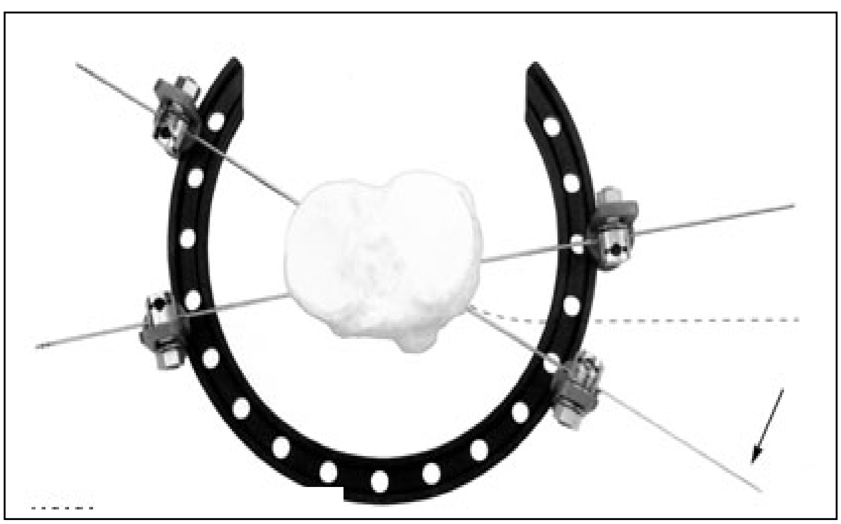
- Increasing the number of wires in proximal fragment
- Adding a schanz screw in proximal fragment
- A minimum of three schantz screws are needed for each fragment in case of diaphyseal extension.
- Adding a third rod to the apparatus
- Triangulating the fragment.

PREOPERATIVE PLANNING

- X ray of the knee joint / ankle joint AP and Lateral view taken. The need for reduction of articular surface is assessed.
- The articular surface is reduced and fixed with cancellous screws



- Metaphysial fragment is fixed with two ilizarow wires and connected to a 5/8th ring. For additional stability an extra ilizarow wire can be added. For fixation of additional fragments olive wires are used.



- Tensioned ilizarow wires in metaphyseal fragments gives good hold and stability than screws. It also gives multiplanar fixation and aids in early joint mobilization.
- In case of periarticular fractures of tibia extending to diaphysis is 3 schantz screws are inserted in proximal fragment and three schantz screws in distal fragment, to give adequate stability to the fracture site.
- Two AO rods are connected to the 5/8th ring and are triangulated. Triangulation gives 360 degree stability which are comparable to a full ring. For additional stability an additional rod can be used.

SURGICAL TECHNIQUE

Preoperative planning

- Evaluate the need for distraction to aid reduction.
- Assess articular surface involvement.
- Plan and determine proper wire and Schanz screw placement

TECHNIQUE

PROXIMAL TIBIA

1. Reduce the articular surface

- Ligamentotaxis is achieved using femoral distractor
- If needed open reduction and bone graft.
- Screw fixation using 6.5mm cancellous screws provides interfragmentary compression for the articular fragments

2. Determine wire position

- Minimum of two wires is needed.
- Position wires within the zones for safe pin placement (location of the peroneal nerve should be noted).
- Position the wires distal to cannulated screws and distal to the capsular attachment of the knee joint.
- The location of wires to be used in proximal tibia is
  - A. Anterolateral to posteromedial tibia
  - B. Lateral to medial tibia

- Wires inserted should be below 14mm to joint line to avoid entry into synovial recess posteriorly to avoid septic arthritis secondary to pin tract infection
- Recently communication between tibiofibular joint and knee joint was found. So fibular head should not be included in the wire insertion.
- If a fragment is to be reduced an olive wire can be inserted

3. Insert wires
   - Make a stab incision and insert a Protection Sleeve
   - Manually push the wire through the sleeve until it contacts the bone.
   - Alternatively, push the point of the wire through the skin without making an incision. Do not change the wire direction after insertion.
   - When the wire has pierced the opposite cortex proceed with gentle blows of the hammer,
4. Place clamps on wires (central and eccentric)
5. Attach clamps to ring- 5/8th ring
6. Tension wires
   - First wrench-tighten the wire-locking nut on one side and finger tighten the wire-locking nut on the other (tensioning) side

- apply the tensioner to the wire and tension it
- wires are generally tensioned to 100-130 kg.

7. Attachment to AO rod to ring using male clamp or hybrid clamp

8. Additional rods attachment

Distal Tibial Fractures:

- Apply distraction using distractor
- Fix associated fibular fracture to restore correct length, rotation and alignment
- Restore the articular surface
- Two typical wire positions :

A. Anterolateral to posteromedial tibia

B. Lateral to medial tibia

COMPLICATIONS

The surgical treatment for periarticular fractures of tibia now has a better outcome than in the past because of improved implants. However the new methods are not without problems.

Complication of fractures:

1. Infection
2. Vascular injuries
3. Nerve injuries
4. Nonunion
5. Malunion
6. Pulmonary complications
7. Missed ligamentous injuries
8. Knee stiffness

Complication of operative treatment:

1. Incomplete reduction
2. Incongruous reduction
3. Loss of knee motion
4. Infection

INFECTION:

The major draw back of operative fixation of periarticular fractures of tibia is the risk of infection. However it should not exceed 5%. If wound drainage develops postoperatively, aggressive irrigation and debridement are indicated. Appropriate antibiotics should be given intravenously for 3 to 6 weeks. In the presence of infection, the implants should be retained because stable infected fractures are easy to manage than unstable infected fractures. However if the implant is loose, it should be removed and the fracture should be protected with external fixation.

NONUNION:

It is much more common in conservatively treated cases than in surgically treated cases, owing in part to the rich blood supply to the proximal tibia and the predominance of cancellous bone. Nonunion generally is due to presence of infection, unstable fixation, mechanical failure of the implant or any combination of these factors. Treatment may be difficult owing to preexisting osteopenia, proximity to knee joint and prior surgical procedures. Aseptic nonunion should be treated by repeat osteosynthesis. Septic nonunion should be treated with external stabilization.

POST TRAUMATIC ARTHRITIS:

The incidence of post traumatic arthritis is unknown. However incongruity of the joint surface is the leading cause of the early arthritis. Unfortunately lot of patients developing post traumatic arthritis is young patient becoming unsuitable for TKR. This complication can be reduced by anatomical reduction and early mobilization. In patients where it is limited to one compartment, a corrective osteotomy may be indicated. In patients with severe disabling bicompartmental or Tricompartmental arthritis, knee arthrodesis (or) TKR may be necessary. Factors such as age, range of motion, presence or absence of flexion contractures and infections play a major role in surgical decision making.

KNEE STIFFNESS:

Perhaps the most common complication that occurs after tibial plateau fracture is loss of knee motion. This untoward complication invariably results from damage to joint surface as a consequence of initial trauma (or) surgical exposure for fixation (or) both. Arthrofibrosis of the knee joint is thought to restrict knee movement. These effects are greatly magnified by immobilization after fracture, or internal fixation. Immobilization of the knee for a period of more than 3 weeks usually results in some degree of permanent stiffness.

Early stable fixation of the fracture with meticulous soft tissue handling and immediate mobilization of the knee maximize the chance for an optimal outcome after periarticular fractures of tibia. Patients should have 90^0 of knee flexion 4 weeks postoperatively. Patients who failed to regain at least 90^0 of knee flexion between 8-10 weeks postoperatively usually warrant additional treatment. Arthroscopic lysis with manipulation can be done. Forcible manipulation should be avoided.

VASCULAR INJURIES:

The exact incidence of vascular injury accompanying proximal tibial fracture is unknown but is estimated to be only 2-3 %. Vascular injuries can be caused by direct laceration (or) contusion of the artery or vein by fracture fragments or indirectly by stretching leading to initial damage, clinical examination for signs of ischemia with evaluation of pulses and motor and sensory function is essential.

MALUNION:

Malunion of one or both tibial condyles, distorts the articular surface of the knee, but it produces much more severe disability. It should be corrected and internally fixed with maintaining the articular surface.

PULMONARY COMPLICATIONS

When stabilization of the fractures was delayed in patients who had multiple injuries, the incidence of pulmonary complications was higher, patients who were treated conservatively or with late stabilization of fractures in polytrauma had high incidence of fat embolism (22%).

ASSOCIATED LIGAMENTOUS INJURIES

Concomitant ligamentous injuries to the knee are common but are rarely diagnosed preoperatively. Initially non operative treatment is advocated as repair (or) reconstruction may produce further comminution, prolonged operation time and increases the risk of loss of knee motion and infection. Protected motion in conjunction with a knee orthosis and vigorous rehabilitation may obviate the need for late reconstructive surgery. If necessary late reconstruction should be done after the fracture has healed.

EVALUATION OF OUTCOME

There is a lot of scoring system for evaluation of outcome. We followed the rating system of Neer for evaluation of knee. Other systems like the hospital total knee care system and Schatzker system are more complicated to follow:

NEER'S RATING SYSTEM:

CHARACTER	**SCORE**	**DEFINITION**
Pain	4	No pain in all ranges of motion
	3	Pain with normal daily activity
	2	Minimal activity gives pain
	1	Pain at rest
Movements (In degrees)	4	Flexion > 120 ; No FFD
	3	Full Extension, flexion 90 to 120
	2	Loss of Extension less than 10 ; Flexion 70^0 to 90^0
	1	Flexion < 60
Function	4	Full weight bearing, Normal gait, No functional impairment
	3	Limp, No restriction of activity
	2	Requires walking aid
	1	Cannot walk
Shortening (cm)	4	0 – 0.5 cm
	3	0.5 to 2.5 cm
	2	2.5 to 5 cm
	1	> 5 cm

Angulation (degree)	4 3 2 1	None $< 10^0$ $10\text{-}15^0$ $> 15^0$

Result	**Score**
Excellent	16 – 20
Good	12 – 16
Fair	8 – 12
Failure	4 - 8

We follow Tornetla et al scoring 39 for evaluation of ankle

GRADE	**PAIN**	**ROM**	**ANGULATION**
EXCELLENT	None	Dorsiflexion > 5 Plantarflexion > 30	<3
GOOD	Intermittent	Dorsiflexion 0 - 5 Plantarflexion 20 - 30	3-5 valgus < 3 varus
FAIR	Limiting daily activities	Dorsiflexion > -5 to 0 Plantarflexion 15-20	5-8 valgus 3-5 varus
POOR	Intractable	Dorsiflexion < -5 Plantarflexion < 15	>8 valgus >5 varus

MATERIALS AND METHODS

The period of surgery and follow up extends from November 2006 to November 2008

It includes all grades of proximal and distal tibia fractures. Pathological fractures and fractures in children were excluded.

The cases were analyzed as per the following criteria.

1. Age distribution
2. Sex distribution
3. Side of injury
4. Mode of injury
5. Anatomy of injury
6. Associated injuries
7. Open fractures
8. Duration for surgery
9. Time of union

1. AGE DISTRIBUTION

The age groups varied from 21 years to 51 years with the mean age of 36.5 years. Incidence of fracture was observed maximum between 30- 40 years of age.

Age Group	**Number of cases**	**Percentage**
20 – 30 years	3	16.7%
30 – 40 years	11	61%
40 – 50 years	3	16.7%
50 – 60 years	1	5%

2. SEX

Among the 18 cases, males were predominant with female to male ratio being 1:19

Sex	**Number of cases**	**Percentage**
Male	17	95 %
Female	1	5 %

3. SIDE OF INJURY:

Right side was common in our series

Sex	**Right**	**Left**	**Percentage**
Male Female	10 0	7 1	56 % 44%
Total	10	8	100%

4. MODE OF INJURY:

Commonest mode of injury has been road traffic accident

Mode of Injury	**Number of cases**	**Percentage**
RTA Fall	18 0	100 % 0%

5. ANATOMY

SITE	**Number of cases**	**Percentage**
Proximal tibia Distal tibia	9 **9**	**50%** **50%**

6. ASSOCIATED INJURIES

Head injury – 2

Distal radius fractures - 1

Patella fracture - 4

Supracondylar fracture femur - 1

7. OPEN FRACTURES

Type	Number of cases	Percentage
Simple	5	28 %
Compound Gr II	2	11 %
Compound Gr III A	4	22 %
Compound Gr III B	7	39 %

8. DURATION FOR SURGERY

TIME INTERVAL	Number of cases	Percentage
1 day	**6**	**34**
< 1 week	**8**	**45**
<2 weeks	**4**	**21**

9. TIME OF UNION

Time of union	Number of cases	Percentage
< **4** months	**11**	**66**
4-6 months	**4**	**23**
>6 months	**2**	**11**

OBSERVATION

- 80**%** of the patients were between 30- 50 yrs.
- Both male and female were included , majority being males.
- Right side was common and was no bilateral cases studied.
- 72% of the fractures were compound injuries.
- 45% of patients had associated injuries.
- Mean duration between injury and surgery was 1 week.
- 5 patients required additional surgeries like flap cover and SSG (two immediately and others within 3 weeks).
- Average time for bone union was 4 1/2 months.
- Average knee joint flexion was 100 degrees and ankle dorsi flexion was 20 degrees.
- The results were excellent in 54%, good in 29% and fair in 17% of patients.

PROCEDURE

General Measures

All the patients were received in the casuality department and were resuscitated. After the general condition improved X rays AP and lateral views were taken. A detailed preoperative work up was done. All the cases were taken for surgical procedure as soon as possible. Those cases which were compound were initially treated with external fixator.

POST OPERATIVE PROTOCOL:

Second post op day:

ROM exercises started along with quadriceps Exercises. Partial weight bearing started if bone grafting not done and delayed till 6 weeks if grafted for settling of graft (None of our patients were grafted, so all the patients were started partial weight bearing immediately).

After 6 weeks:

- Full weight bearing is started after radiological signs of union appear (full weight bearing was started at an average of 6 weeks. In 3 of our patients it was delayed for 2 months due to poor radiological signs of union).
- Fixator is removed after fracture is united radio logically

- Regular check up is done for half pin pull out, loss of wire tension, deformity in half pins, side rod or 5/8th ring. Pin site care is given according to oxford protocol 24.

Care in operating room – pin site dressing with non adhesive dressing

For 48 hrs – pin site not disturbed

After 48 hrs –

1. clean frame with normal saline prior to removing pin site dressing
2. clean each pin site with separate gauze and normal saline
3. cover half pin and wire site with nonadhesive dressing
4. continue daily pin dressing

After one week

- continue daily wash with cotton gauze and saline
- take daily shower
- leave all pin sites uncovered

Pin site infection is treated with twice daily dressing, oral antibiotics.

FOLLOW UP:

All the patients were followed up carefully looking for any complication every fortnightly till fracture healing. And there after every monthly upto 6 months. And every 6 monthly up to two years.

ANALYSIS OF FUNCTIONAL OUTCOME

Total 18 patients are included in the study. One case went for septicemia and went for amputation. Other patients are evaluated and studied for functional outcome.

Normal bone union	–	15
Delayed union	–	2
Shortening	–	2
Joint stiffness	–	2
Varus angulation	–	2
Pin tract infection	–	4
Deep infection	-	2

OVERALL RESULTS

GRADING	**NO OF CASES**	**PERCENTAGE**
EXCELLENT	9	54
GOOD	5	29
FAIR	3	17

DISCUSSION

All the methods available for fixation of periarticular fractures of tibia have good fracture union results but they do not address all of its problems. The main problem of these fractures is severe communition and more chance for compound injuries which becomes difficult to be managed by open reduction and internal fixation. Even in closed injuries internal fixation results in skin problems. Soft tissue handing becomes the important criteria in the treatment of these fractures since it preserves the hematoma aiding in quick fracture healing. Also it helps in early joint mobilization thus preventing joint stiffness.

In case of compound fractures wound care becomes the prime importance. In needs the preliminary application of a external fixator followed by definitive mode of fixation after the wound has healed. But the application of hybrid external fixator not only helps in wound care but also is a definitive mode of fixation. This avoids two procedures for these patients thus decreasing the stress for the patients and economically friendly. The compliance of hybrid fixator is better than ilizarov fixator. Also the simplicity of structure of this apparatus helps in easy application of flap covers which is mostly needed in the due course of treatment of compound injuries, which is not possible in case of ilizarov apparatus.

In our study of 18 cases of which 13 are compound cases 5 are simple cases, hybrid fixator was applied in a mean time interval of 8 days. Time interval ranged from day one to 2 weeks. The delay in surgery was mainly due to medical problems of the patient.

All the cases were followed for a mean period of 14.2 months averaging from 28 months to 4 months. Out of the 18 cases bony union was obtained in 17 cases (one of which was converted to ilizarov since there was a bony defect after which bone transport and bony union was obtained) and one patient went for below knee amputation due to impending septicemia. 2 cases had delayed union one of which maintained by prolonged PTB cast and one with fibulectomy. Main reason for delayed union was intact fibula which made the fracture site to distract. Even though hybrid provides axial micro movement, compression cannot be applied to fracture after the application of fixator which will be possible in ilizarov fixator. So at the time of application fracture site should not be over distracted and particular attention should paid in proper reduction of fracture. Comparing the other studies Barberie et al [31] reported 3 non union in 34 patients managed by hybrid fixcator, one case of non union in 31 patients in Tracy et al [41] study and no non union out of 13 cases in a series by Kevin J Pugh.

There was one case of failure in a case of compound grade III b fracture with severe contamination. This was due to severe infection and extensive bone loss. Since the patient went to septicemia removal of fixator was done and below knee amputation was done. This would have been avoided by proper selection of case.

The average time of bony union was 4.5 months compared to 4 months by Barberi et al [33] and 4.2 months by Tornetla et al.

There were 4 cases of pin tract infections all which got settled without surgical intervention. This was attributed to poor pin site care by the patients after their discharge. There were two cases of deep infection one persisted even after fixator removal which was treated by antibiotics. Other patient presented lately after union in the site of Tension Band Wiring applied for patella which settled after removal of implant.

There were 2 cases that were complicated by knee stiffness. Both the patients had poor compliance in the post operative period which was the result of knee stiffness.

One patient had knee instability which persisted after union of fracture which was treated conservatively knee brace. Shortening of <2 cm was seen in two patients both of which had highly communited tibial plateau fractures with diaphyseal extension. They were managed with heal rise.

CONCLUSION

To summarize, the advantages of hybrid external fixator are

- minimally invasive procedure
- good preservation of soft tissues
- better anchorage of thin tensioned wires than half pins in cancellous bone and they give better stability.
- easy application of half pins in diaphysis without neurovascular injury
- early mobilization of adjacent joint
- good skin care and easy application of flap cover
- less heavier than ilizarov gaining good acceptance of the patient.

The disadvantages of hybrid fixator are

- risk of articular infection if pins are applied very close to joint
- tough to obtain articular reduction
- the radio opaque ring obstructs x ray visualization of fracture

Hybrid External Fixator is very effective and useful treatment modality for periarticular fractures of tibia. It aids in providing good skin Care and it is easy for application of flap covers which is difficult in case of ilizarov circular fixators. It also acts as a definitive fixation aiding in good fracture union thereby avoiding multiple surgeries in compound fractures.

Hybrid External fixator is a modular, safe and useful treatment option for complex periarticular fractures of tibia. It is minimally invasive with least complications compared to other methods which are used for peri articular fractures of tibia.

BIBLIOGRAPHY

1. Ali AM, Saleh M, Bolongaro S, Yang L. The strength of different techniques for bicondylar tibial plateau fractures – a biomechanical study. Clinical bio mech(Bristol, Avon; Nov 2003, Vol 1819), No 864-870.
2. Allan.F. Tencer, Kenneth.D.Johnson, Biomechanics in orthopaedic trauma. 1st edition, 1994, Lippincott.
3. Behrens F. Manual of internal fixation – Technic recommended by AO – ASIF Group 1990, 3rd edition, chapter 5 , NO 367-411.
4. Benedetti G.B, Argneni.F – A.S.A.M.I group, operative principles of ilizarov, Williams and Wilkins.
5. Beris A E, Glisson RR, Seaber Av, Urbaniak JR. “ Load tolerance of tibial plateau depression with cluster of K wires”. Trans 34th Orthopaedic research society meeting 1988; vol 13, No 30.
6. Bonel, Stegemann P, Mc Namara K, Seibel R. External fixation of severely communited and open tibial pilon fractures. Clinical orthop; 1993, vol 297, No 101-107.
7. Bronson DG , Samchukor MC, Birch JG. Journal peadiatric orthop B; 2002 April, vol11, No 143-149.

8. Calhoum JH, LiF, Ledbetter BR , Gill CA. Biomechancs of ilizarov for fracture fixation. Trans 37th orthopaedic Reserch Society Meeting 1991; vol 16, No 438.
9. Browner and Jupiter, Text book of skeletal Trauma; 2nd edition Chapter 56, No 2316 – 2324.
10. Catagni M- A.S.A.M.I group, operative principles of ilizarov, Williams & Wilkins.
11. Decoster TA , hertderns DB, Downey DJ , Ferries JS, Jones W. Optimizing bone screw pull out force. Journal of orthopaedic Trauma; 1990, vol 4, No 169-174.
12. Dror paley. Problems, obstracles and complications of limb lengthening by illizarow technique. Clinical orthop;1990, vol 250, No81-104.
13. Egan JM, Shearer JR. Behavior of an external fixator frame incorporating an angular separation of fixator pins; a finate element approach. Clinical orthop; 1987, vol223, No 265-274.
14. Endres T, Grans R, Biewener A, Barthal S, Zwippu. Advantages of minimally invasive reposition retension and hybrid external fixator for tibial pilon fractures with particular emphasis on C2/C3 fractures. Unfallchirulg;April 2004, Vol107(4),No 273-284.

15. Gaudinez RF, Mallik AR, Szporn M .Hybrid external fixator of common tibial plateau fractures. Clinical orthop; 1996, vol 328, No 203-210.
16. George W wood, Campbells operative orthopaedics; 2003, 10th edition, Chapter 50, No2671-2723.
17. Halsey D, Fleming B, Pope MH, Krag M, Kristiansen T. External fixator pin design. Clinical orthop, 1992; vol 278, No 305- 312.
18. Joyne PH, Rochat MC, Hoover JP. Use of hybrid external fixator for repair of periarticular tibia fractures in a Patagonian cavy. J AM vet med assoc; Apr 2004, vol 224(8), No 1298- 1301.
19. Kevin J pugh, Philip R wolinshy, Mark P Mc Andrew, Kenneth D Johnson. Tibial pilon fractures; a comparision of treatment methods. Journal of trauma; 1999, vol 47, No 937-941.
20. Lerner A , Stein. Hybrid thin wire External fixator; an effective minimal invasive, modular surgical tool for the stabilization of periarticular fractures. Journal of orthopaedics, Jan 2004, vol 27(1), No 59-62.
21. Madhor A Karunakar, Micheal J bose. Rockwood and Greens " Fracture in adults". 2001; 5th edition, chapter 7, No 231-245.

22. Mark Farrar, Lang yans, Micheal salen. The Sheffield Hybrid Fixator- a clinical and biomechanical review. INJURY; 2001, vol 32, No 8-13.
23. Marsh JL , Smith ST, DOTT. External fixator and limited Internal fixation of complicated fractures of Tibial plateau. Journal of Bone and Joint surgery 1995; May vol 77A, No 661-673.
24. Martin A McNally, Maurizio A Catagni. Oxford’s textbook of orthopaedics, chapter 6, No 1735-1748.
25. Michael S Sirkin, Christopher M Bono, Mark c Reilly, Fred F Behrens. Percutaneous methods of tibial plateau fixation. Clin orthop and related research; 2000, vol 375, No 60-68.
26. Ovadia.DN, Beals RK, Fractures of tibial plafond. Journal of Bone and Joint surgery; 1986, vol 68A, No 543-551.
27. Paige Whittle A, George W Wood, campbells operative orthopaedics; 2003, 10th edition, chapter 51, No 2726-2872.
28. Persen SM, Cardey J, Baumgart F, Rahh BA, Schatzker J. Technical and Biomechanical aspects of screws used for bone screws. International journal of orthopaedic Trauma; 1992, vol 2 No 31-48.

29. Pugh KJ, Wolinsky PR, Dawson JM, Stalhman GC. The biomechanics of Hybrid external fixator. J orthop Trauma; 1999, vol 13 No 20-26.
30. Raschke MJ , Hoffman R, khodadyan C, Fournier CV, Sudkann NP,Hoas NP. Combination of ilizarov ring fixator with unilator AO tubular fixator; initial clinical experience with hybrid system. Unfallchirury; 1995, vol 98, No 627-632.
31. Robern CS, Antoci V, Antoci V Jr, voor MJ. The accuracy of fine wire tensioners: a comparision of 5 tensioners used in hybrid and ring external fixator. J orthop trauma; march 2004, vol 18(3), No 158-162.
32. Robern CS, Dodds Jc, Pery K, Berk D, Selingson D, Voor MJ. Hybrid external fixator of proximal tibia: stratergies to improve frame stability. Journal of orthop trauma; 2004 Jan, vol 18 No 57.
33. Rouo Barbieri, Richard Schenk, Kenneth kovel, Kevin Aurori, Brian Aurori. Hybrid external fixator in treatment of tibia plaford fractures. Clinical orthop and related research; 1996, vol 332, No 16-22.

34. Reudi TP, Allgower M . The operative treatment of Intra articular fractures of lower end of tibia. Clin orthop 1979, vol 138, No 105-110.

35. Schatzker J, Sanderson R, Murnaghan JP. The holding power of orthopaedic screws in vivo. Clinical orthop; 1975, vol 108, No 115-126.

36. Stamer D, Schenk R, Staggers B. Bicondylar tibial plateau fractures treated with Hybrid external fixator, a preliminary study. Jour orthop trauma; 1994, vol 8, No 455-461.

37. Steink, Mosheiff R, Baumgart F, Frigg R, Perren SK, cordey J. the hybrid external fixator: a biomechanical study. Clin Biomechanics; 1997, vol 12, No 259-266.

38. Thakur AJ. Elements of fracture fixation, 1997; 1st edition. Chapter 8, no 147-176.

39. Tornetta P, Weiner L, Bergman metal, Pilon fractures treated with combined internal and external fixation. Journal of orthop trauma 1993, vol 7, No 489-496.

40. Tracy Watson J. High energy fractures of tibial plateau. OCNA; oct 1994, vol 25, no 723-752.

41. Tracy Watson J, Steve Ripple, Hoshaw, David Fyhrie . Hybrid external fixator for tibial plateau fractures. OCNA; jan 2002, vol 33, No 199-209.

42. Uhthoff HK. Mechanical factors influencing the holding power of screws in compact bone. JBJS; 1975, vol 55B No 633-639. vol 77A, NO661-673.

43. Weiner L, Kelly M, Yans E. The use of combination of internal fixation and hybrid external fixation in severe proximal tibia fractures. Journal of orthopaedic trauma; 1995, vol 9, No 244-250.

44. Yilmaz E, Belhes O, Karakuet L, Arslan N, Serin E. Mechanical performance of hybrid external fixators in comparision with Ilizarov circular external fixator. Clinical BIOmechanics(Bristol, Avon); Jul 2003,Vol 18(6), No 518-522.

PREOPERATIVE WOUND

PRE OPERATIVE X RAY

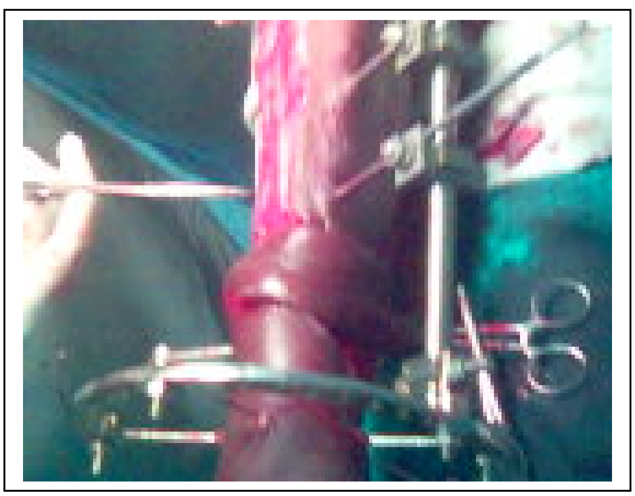
X RAY SHOWING FRACTURE UNION

FUNCTIONAL OUTCOME

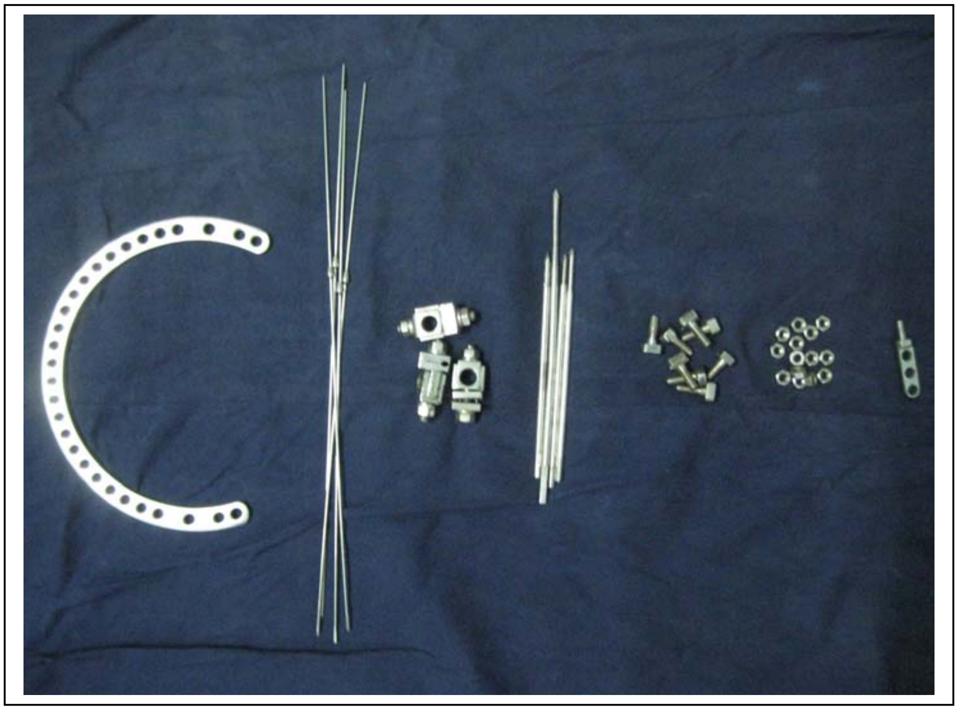
SOFT TISSUE COVERS DONE

SSG

FASCIO CUTANEOUS FLAP COVERS



IMPLANTS USED



INTERCONNECTING SYSTEM

COMPOUND GRADE III B PROXIMAL TIBIA FRACTURE

PREOPERATIVE WOUND

PREOPERATIVE X RAY

FASCIO CUTANEOUS FLAP

POST OPERATIVE

KNEE FLEXION

REVIEW X RAY

PREOPERATIVE X RAY

POST OPERATIVE X RAY

3 MONTHS REVIEW X RAY

ANKLE MOVEMENTS

COMPOUND GRADE III B DISTAL TIBIA FRACTURE

PREOPERATIVE WOUND

POST OPERATIVE X RAY

FLAP COVER

4(M) REVIEW

FOLLOW UP

SIMPLE PROXIMAL TIBIA FRACTURE SCHATZKER TYPE - VI

PREOPERATIVE X RAY

POST OP.

3 ½ MONTHS REVIEW X RAY

RANGE OF MOVEMENTS

SIMPLE PROXIMAL TIBIA FRACTURE SCHATZKER TYPE - VI

PREOPERATIVE STATUS

PRE OPERATIVE X RAY

POST OPERATIVE X RAY

FUNCTIONAL OUTCOME

MASTER CHART

S.No.	Name	Age//sex	IP No.	Diagnosis	Asso.Injuries	DOA	DOS	Treatment	Other procedures	Time of Union	Range of movements DF PF Flex	Complications	Results
1	Bala murugan	38/M	37630	Comp.Gr.IIIB tibial plateau # Rt	Head Injury	27-5-07	11-6-07	Two 6.5mm cancellous screws and hybrid fixator	-	5½ months	30 40 100	-	Excellent
2	Chella pandi	32/M	28621	CompGr.IIIB proximal tibia # Rt	-	6-4-07	6-4-07	Hybrid fixator	Immediate fascio cutaneous flap & SSG	7 months	20 40 90	Wound infec tion	Excellent
3	Chinnap pan	34/M	51085	CompGr.IIIA proximal tibia # Lt	Verti cal patella #	17-7-07	18-7-07	OR & IF with 4mm malleolar screw for patella & tibia # & hybrid fixator	-	4 months	20 40 130	Pintract infec tion	Excellent
4	Ganesan	21/M	39610	Comp.Gr.IIIB tibial plateau # Rt Type VI	Comp.Gr. IIIB SC # femur	4-3-07	26-3-07	Hybrid fixator	OR & IF of SC # with LCP	6 months	20 40 40	Knee stiff ness	Fair
5	Siva raman	33/M	29781	Simple BB leg # L ¼ left	-	3-3-07	8-3-07	OR & IF of fibula with 1/3 tubular plate & hybrid fixator	-	3 ½ months	20 40 130	-	Excellent
6	Raja lakshmi	36/F	38210	CompGr.IIIA BB leg # L ¼ left	-	28-5-07	31-5-07	Hybrid fixator	Immediate SSG	4 months	20 40 130	-	Good
7	Kalidass	27/M	22655	Comp.Gr.IIIB tibial plateau # Lt Type VI	Communi ted patella #	15-1-08	29-1-08	Patellectomy with hybrid fixator	SSG (After 20 days)	4 ½ months	20 40 60	Knee stiff ness	Fair
8	Kesavan	45/M	23782	CompGr.IIIA proximal tibia# Rt	Distal radius # Rt	9-5-07	17-5-07	CR & IF with hybrid fixator	-	4 months	20 40 130	Valgus in stabi lity	Good
9	Moorthy	40/M	31274	Comp.Gr.IIIB tibial plateau # Rt Type VI	Communi ted patella #	18-4-08	18-4-08	OR & IF of patella with circlage wire and transverse	-	5 months	20 40 100	Varus collapse pin tract	Fair

								malleolar screw & hybrid fixator					infection	
10	Rathinam	36/M	29241	Simple BB leg # L 1/3 Rt	-	24-3-07	26-3-07	OR & IF of fibula with 1/3 tubular plate & hybrid fixator, 2 lag screw for tibia	-	3 ½ months	20 30 130		-	Excellent
11	Alagar	22/M	30081	Simple BB leg # L ¼ left	-	1-6-07	4-6-07	CR & IF of # with hybrid fixator	-	4 months	20 40 130		5 degree varus	Good
12	Muru gesan	45/M	32817	CompGr.IIIB leg # L 1/3 Rt	-	22-6-07	22-6-07	K wire for fibula and hybrid fixator	BK amputation	-	-		Gross infection & went for septi cemia	
13	Neela vannan	38/M	36281	CompGr.IIIA BB segmental leg # L 1/3 Rt	-	8-9-07	9-9-07	CR & IF with hybrid fixator	Flap cover (25^{th} day) later converted to Ilizarov for segmental transport	8 months	10 20 120		-	Good-fair
14	Sahul hameed	35/M	31181	Comp.Gr II BB leg # L 1/3 Lt	-	30-7-07	30-7-07	CR & IF with hybrid fixator	-	3 ½ months	10 40 130		Pin tract infection	Excellent to Good
15	Mani	36/M	28121	Simple tibial plateau # Lt Type VI	-	23-12-06	26-12-06	CR & IF with hybrid fixator & 2 cancellous screws	-	3 ½ months	20 40 130		Shorten ing 0.5 cm	Excellent
16	Kalai vanan	42/M	30012	Simple tibial plateau # Lt Type VI	-	6-2-07	12-2-07	CR & IF with hybrid fixator & 2 cancellous screws	-	4 months	20 40 110		Pin tract infection	Excellent
17	Paulraj	40/M	27181	Comp.Gr.IIIA tibial plateau # Rt Type VI	Commu nited patella #	15-1-07	25-1-07	OR & IF of patella with TBW and hybrid fixator	Metal exit for patella	3 ½ months	20 40 100		Varus ang. 15 degrees Infection shorten ing 1 cm	Good
18	Subra mani	51/M	21261	CompGr.IIIB BB leg # L 1/3 Rt	-	12-1-07	13-1-07	Hybrid fixator	Flap cover 23^{rd} day	3 ½ months	10 30 130		-	Excellent